Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of	)	
MITIGATION OF ORBITAL DEBRIS IN THE NEW SPACE AGE	)	IB Docket No. 18-313

FURTHER COMMENTS OF SPACE EXPLORATION TECHNOLOGIES CORP.

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SUMMARY

SpaceX welcomes the Commission's continued focus on maintaining a safe orbital environment. SpaceX fundamentally relies on maintaining a clean orbital environment for every aspect of its business, including as one of the world's most active providers of launch services, provider of transport for astronauts and cargo to the International Space Station ("ISS"), and the licensee of a non-geostationary orbit ("NGSO") satellite system that is initiating truly high-capacity, low-latency broadband services to Americans even in areas underserved or completely unserved by terrestrial alternatives. In the first phase of this proceeding, SpaceX proposed what may have been the strongest set of policies to encourage safe operations in space. SpaceX was encouraged to see the Commission update its orbital debris mitigation rules in a number of productive ways. This second phase provides an opportunity for the Commission to consider additional strategies for safeguarding operations in space for all who seek to make productive use of orbital resources. SpaceX specifically encourages the Commission to update its rules to more fully account for the number of years that objects remain in orbit, which has a direct effect on the risks those objects pose.

But no matter how strong the policies, no update to the Commission's rules can be effective if applied only to the small number U.S.-licensed systems. The Commission should reconsider its decision to preserve the foreign-licensee loophole, consistent with SpaceX's Petition for Reconsideration.

Additionally, SpaceX supports several Commission proposals that would impose more stringent space safety requirement for NGSO systems. In particular, SpaceX would (1) require that all low-Earth orbit ("LEO") satellites operating above the 400 km altitude at which the ISS is located must have maneuver capability sufficient to avoid collisions; (2) shorten post-mission

orbital lifetime for satellites from a maximum of 25 years to no more than 5 years after mission completion; and (3) require that satellites demising in the Earth's atmosphere present zero risk of human casualty, though the Commission could allow up to a maximum of the current 0.001 probability if appropriate in a specific case. By requiring more capable spacecraft with shorter duration in orbit and design-for-demise construction, the Commission would not only enhance the operational environment for all NGSO systems, but also help maintain the satellite industry's perfect safety record with respect to human casualties from de-orbited satellites.

SpaceX also continues to support the Commission's requirement that NGSO systems comply with a maximum per-satellite collision risk metric. Whether proposals to revise this standard to apply across entire U.S.-licensed constellations provide any benefits is unclear, while the harm caused by stifling the ability of U.S. licensed systems to provide service to American consumers is clear and would far outweigh any purported benefit. SpaceX agrees with NASA, which specifically did "not recommend applying this requirement in an aggregate manner for constellations." An aggregate metric could impose widely-varying requirements on satellites that are otherwise operationally equivalent, resulting in the application of less stringent regulations to some satellites than others, based only on how many satellites are covered by that operators' license – not on the actual safety profile of the spacecraft.

Rather than an aggregate metric, the Commission has an opportunity to update its calculations for collision risks that could provide certain and dramatic benefits to space safety. Specifically, the Commission's policies should reflect the differences in persistence and size of orbital debris, because even just a few long-lasting objects that survive for decades, centuries, or even millennia cause significantly more harm than objects that the atmosphere sweeps away quickly. Accordingly, SpaceX proposes to maintain a per-satellite risk requirement, but to apply

a hybrid approach that incorporates assumptions about individual satellites and an NGSO system as a whole to determine a mean per-satellite collision risk value. This would better reflect the likely and persistent risks presented by a proposed system while recognizing the importance of having sufficient satellites to close the digital divide with low-latency, high-throughput service.

SpaceX supports the Commission's ongoing efforts to update its orbital debris mitigation regime—a process that is especially important given the growth in and dynamic nature of satellite systems. The Commission should take this opportunity to build upon the rules it recently adopted by revising them where appropriate to achieve greater safety but should avoid policies that would be counterproductive. Specifically, the Commission should require maneuverability for LEO spacecraft operating above the ISS, shorten post-mission orbital lifetime, and require zero calculated risk to human life on the ground.

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Space Exploration Technologies Corp. ("SpaceX") submits these further comments in response to the Further Notice of Proposed Rulemaking ("*FNPRM*") issued by the Commission in this proceeding.[1] In the first phase, the Commission adopted a number of new rules that were intended to "mitigate the growth of orbital debris, while at the same time not creating undue regulatory obstacles to new satellite ventures . . . consistent with the public interest in space remaining viable for future satellites and systems and the many services that those systems provide to the public."[2] The *FNPRM* requests comment on several more topics that apply most directly to non-geostationary orbit ("NGSO") satellite systems, a highly dynamic and fast-growing segment of the industry that is just beginning to realize its potential.

SpaceX appreciates the careful balance the Commission must strike to maintain a safe environment, while supporting systems that can help close the digital divide and provide other services to American consumers. Nonetheless, SpaceX also strongly supports the Commission's goal of making space safer for current and future uses. To be effective, this commitment to safety

[1] *See Mitigation of Orbital Debris in the New Space Age*, Report and Order and Further Notice of Proposed Rulemaking, 35 FCC Rcd. 4156 (2020) ("*FNPRM*").

[2] *Id.* ¶ 1.

must extend to everyone in the space community rather than requiring just a few commercial communications satellite operators to carry the burden for all. To ensure its rules are effective, the Commission should reconsider its decision to preserve the exemption for foreign operators from Commission oversight on orbital debris.

BACKGROUND

Maintaining a clean orbital environment is a fundamental consideration for SpaceX, which is planning to launch its Falcon 9 vehicles into orbital altitudes dozens of times this year alone for its commercial and government customers, as well as delivering cargo (with Dragon) and astronauts (with Crew Dragon) to the International Space Station ("ISS"). Indeed, under the current schedule of missions, there will be at least one Dragon spacecraft, and sometimes two, docked to the ISS continuously through the end of 2021 after the launch of the Crew-1 Crew Dragon mission, currently scheduled for October 31.[3]

SpaceX takes seriously its responsibility to protect the shared orbital environment. To meet that responsibility, SpaceX is investing significant resources in an NGSO system capable of operating at low altitude to leverage the built-in advantages of those altitudes to minimize the effect its constellation will have on other operating spacecraft and other orbital resources. SpaceX has designed its system so that normal operations should not generate any debris, but in the unlikely event that any does result, atmospheric drag will ensure that such debris will quickly disintegrate in the atmosphere and pose no further danger to space operations or life on the ground. Moreover, its satellites will have sufficient maneuverability to avoid other satellites and orbital debris throughout their mission lifetime and through completion of the de-orbit process.

[3] *See* J. Foust, *SpaceX has busy manifest of Dragon missions*, SPACE NEWS (Sep. 30, 2020), https://spacenews.com/spacex-has-busy-manifest-of-dragon-missions/.

In the initial phase of this proceeding, SpaceX argued that three overarching policies for orbital debris mitigation will maximize the utility of a safe space environment:

1. Operators should not generate persistent orbital debris, including spacecraft that have completed their mission.

2. Operators should limit their satellites' time on orbit following the end of their mission lifetime.

3. Systems operating in orbits near and above the International Space Station ("ISS") must perform to higher standards that protect human life and important assets.[4]

Those same principles should inform this phase of the proceeding as well.

DISCUSSION

I. THE COMMISSION SHOULD REFINE ITS APPROACH TO ASSESSING COLLISION RISK BUT SHOULD NOT IMPOSE AN AGGREGATE METRIC

In the initial phase of this proceeding, the Commission adopted a requirement that NGSO system applicants must show that the probability of any one of their spacecraft colliding with a large object (i.e., 10 cm or larger in diameter) during orbital lifetime of the satellite will be less than 0.001 (1 in 1,000).[5] In preparing this risk assessment, applicants are to use NASA's Debris Assessment Software ("DAS") or a higher fidelity assessment tool, and may make the simplifying assumption that the collision risk with large objects is zero or near zero during the period of the time when the space station is able to conduct collision avoidance maneuvers. The Commission now seeks comment on a wide range of potential revisions to its approach to assessing collision risk, and in particular how to analyze that risk for multi-satellite constellations.[6] Rather than focus only on the size of a constellation, the Commission should revise its methodology to employ a hybrid approach that will better account for the years objects stay in orbit. While satellites that

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4 *See* Comments of Space Exploration Technologies Corp., IB Docket No. 18-313, at 5 (Apr. 5, 2019).

5 *FNPRM* ¶¶ 33-35; 47 C.F.R. § 25.114(d)(14)(iv)(A)(1).

6 *FNPRM* ¶ 156.

de-orbit quickly minimize their orbital footprint, even a small number of objects can risk the sustainability of space when they remain in orbit for an extended time.

A. An Aggregate Metric Would Be Counterproductive

The *FNPRM* asks whether the Commission should assess the aggregate probability of collision on a system-wide basis, and specifically whether it should use the same 0.001 risk standard that currently applies on a per-satellite basis.[7] This aggregate approach is one that NASA specifically opposed in this proceeding, arguing that instead the Commission should "simply ensure that each launched satellite, whether in a constellation or not, conforms with the 0.001 lifetime collision risk against large objects requirement."[8] SpaceX agrees with NASA that the better approach is to continue to assess collision risk on a per-satellite basis. Aggregate metrics will result in uneven rules allowing some satellites to be less safe than others, depending not on the actual safety characteristics of their operations but on who operates the spacecraft. An aggregate metric could impose widely-varying requirements on satellites that are otherwise operationally equivalent, resulting in the application of less stringent regulations to some satellites than others, based only on how many satellites are covered by that operators' license and not on the actual safety profile of the spacecraft. These rules would be especially ineffective if they are applied only to U.S.-licensed systems.

Indeed, aggregate metrics are not just ineffective – they can harm consumers by effectively capping the service that operators ultimately can deliver without a corresponding benefit in safety. The volume of traffic flowing over the world's networks continues to grow, with one report estimating more traffic in 2022 alone than in the 32 years combined since the internet started, and

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7 *FNPRM* ¶¶ 157-59.

8 Letter from Anne E. Sweet to Marlene Dortch, IB Docket No. 18-313, at 3 (Apr. 4, 2019) ("NASA Comments").

more than six people in ten in the world being online.[9] To address this surging demand, terrestrial network providers are deploying more cell sites, with 4G networks roughly ten times denser than 3G, and 5G networks roughly ten times denser still to deliver the high-capacity and low-latency services that consumers need.[10] Similarly, NGSO satellite operators will need to deploy more satellites to meet the expanding demands of consumers.

But as U.S.-licensed NGSO operators deploy constellations designed to keep up with the public's needs, aggregate requirements will be increasingly difficult to meet. As a practical matter, aggregate metrics will deter operators from adding satellites to their constellations, effectively constraining U.S-licensed operators from improving service for American consumers over time. This approach would thus directly conflict with both the Commission's goal for this proceeding of not imposing "undue regulatory obstacles to new satellite ventures"[11] and its "top priority [of] closing the digital divide so that all Americans can enjoy the many benefits of a high-speed broadband Internet connection – whether job opportunities, remote learning, telehealth, or staying connected to family and friends."[12] And while an aggregate metric will effectively constrain the number of satellites of any one operator licensed in the United States, it will not effectively promote the overall safety of space as incumbent operators and new entrants move to more lax overseas regulatory fora.

Indeed, the Commission is already aware that aggregate deployment limits are not an effective way to encourage broadband deployment, which is why it does not impose them on 5G

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9 News Release, *Cisco Predicts More IP Traffic in the Next Five Years Than in the History of the Internet*, CISCO (Nov. 27, 2018), https://newsroom.cisco.com/press-release-content?type=webcontent&articleId=1955935.

10 *See* Luke Getto, *The Challenges of 5G Network Densification*, MICROWAVE JOURNAL (May 14, 2019), https://www.microwavejournal.com/articles/32235-the-challenges-of-5g-network-densification.

11 *FNPRM* ¶ 1.

12 *Accelerating Wireline Broadband Deployment by Removing Barriers to Infrastructure Investment*, 35 FCC Rcd. 7936, ¶ 1 (WCB 2020).

small cells or any other broadband technology. To the contrary, the Commission has gone to great lengths to promote deployment of additional broadband facilities, even though deploying broadband creates its own risks regardless of the technology used to deliver the service.[13] In fact, the record does not include a single example of the U.S. government actually imposing aggregate metrics on broadband deployment or explain how doing so could result in faster or safer deployment of broadband network infrastructure. To the contrary, in recent years the Commission has taken steps to encourage broadband operators to deploy more extensive terrestrial network infrastructure such as small cells to enhance service for American consumers.[14] Even beyond terrestrial broadband, the record does not include a single example of regulatory or industry bodies having ever embraced aggregate metrics as an effective way to enhance space safety. As the Commission knows, these types of heavy-handed regulations imposed in the aggregate would discourage operators from investing in rapidly evolving low-latency, high-capacity NGSO networks, ultimately leading to reduced service for consumers. Tellingly, aggregate metrics are promoted in the record entirely by operators that chose to license their systems overseas to avoid such requirements.[15]

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[13] *See, e.g.*, Liz Day, *Feds to Look Harder at Cell Carriers When Tower Climbers Die*, PROPUBLICA (Apr. 1, 2014), https://www.propublica.org/article/feds-to-look-harder-at-cell-carriers-when-tower-climbers-die ("Tower climbing, a small field of roughly 10,000 workers, has been called the most dangerous job in America."); Ryan Knutson and Liz Day, *In Race For Better Cell Service, Men Who Climb Towers Pay With Their Lives*, PROPUBLICA (May 22, 2012), https://www.propublica.org/article/cell-tower-fatalities ("Between 2003 and 2011, 50 climbers died working on cell sites, more than half of the nearly 100 who were killed on communications towers.").

[14] *See, e.g.*, *Accelerating Wireless Broadband Deployment by Removing Barriers to Infrastructure Investment*, 33 FCC Rcd. 9088, ¶ 6 (2018) (in adopting rules to promote deployment of small cells, Commission finds that "now is the appropriate time to move forward with an approach geared at the conduct that threatens to limit the deployment of 5G services"); *Accelerating Wireless Broadband Deployment by Removing Barriers to Infrastructure Investment*, 33 FCC Rcd. 7705, ¶ 1 (2018) (one-touch, make-ready order provides expedited access to pole attachments, "continu[ing] our efforts to promote broadband deployment by speeding the process and reducing the costs of attaching new facilities to utility poles").

[15] SpaceX has filed a petition requesting that the Commission reconsider its decision to retain the exception for non-U.S. satellite operators to the rules that protect the orbital environment, or at a minimum clarify what information

The aggregate risk approach also fails to consider other ways to achieve space safety that are more effective and would not inordinately chill NGSO investment. For example, an NGSO operator could follow SpaceX's lead and deploy its satellites at a very low injection altitude, which would allow it to identify a large majority of satellites susceptible to failure at a time when they would naturally de-orbit within a matter of weeks, significantly reducing any chance for them to be involved in a collision. And as discussed above, actually operating at lower altitudes helps to reduce the time during which any failed satellites or related debris would remain in orbit as a collision risk. As NASA has explained, "[t]he calculation of on-orbit collision avoidance residual risk can be approached in different ways and requires a number of assumptions, each of which should sustain formal examination and testing before implementation in order to ensure their reasonableness."[16]

B. Revising the Commission's Methodology for Assessing Collision Risk to Reflect the Persistence of Debris Would Better Capture the Implications of Multi-Satellite Constellations

Although moving to an aggregate collision risk metric would be counterproductive, the Commission can significantly improve its method for assessing collision risk by adopting a more refined approach that considers both the characteristics of individual satellites and those of the systems in which they operate to better capture the actual risks they present to the NGSO environment. The resulting approach would capture the "orbital years" during which a non-maneuverable satellite or related orbital debris would remain a potential collision risk with implications for other NGSO operators, yet could still use collision risk per satellite as a standard.

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is required to meet the newly adopted "transparency" requirement for non-U.S. licensees. *See* Petition for Reconsideration of Space Exploration Technologies Corp., IB Docket No. 18-313 (Sep. 24, 2020).

[16] NASA Comments at 2.

For example, while maneuverable satellites reduce collision risk to a very low figure, the fact remains that they do not actually reduce the risk to zero. When considering an individual satellite, the Commission correctly makes a simplifying assumption that that the collision risk with large objects is zero or near zero during the period of the time when the satellite is able to conduct collision avoidance maneuvers. But in the context of an NGSO constellation, the Commission can refine that assumption by incorporating another assumption applicable to the system as a whole.

Specifically, the Commission should assess mean per-satellite risk as follows:

(1) Calculate the risk of collision for a satellite passively decaying from operational altitude.

(2) Multiply that risk by a probability of non-maneuverability failure that is fixed and consistent with respect to all constellations.

(3) Multiply that result by the mean duration of passive decay for a satellite from operational orbit.

This approach has several advantages. It continues to yield a per-satellite risk metric and thereby avoids the infirmities of an aggregate approach discussed above, while also accounting for potential failures across an NGSO constellation. It also reflects the consequences associated with debris persistence. This hybrid approach more realistically captures the potential risk than simply assuming that all satellites present zero risk if they are designed to be maneuverable.

Moreover, this approach considers the period of the collision risk based on the operational altitude and natural decay profile of the satellite. It creates a metric that combines the probability of a collision with the persistence of that collision's effects, enabling the Commission to consider both the probability of impact and the duration that a failed satellite and/or debris cloud resulting from the impact with this satellite would persist on orbit when assessing risk. This concept thus recognizes that (for example) at an altitude of 250 km, atmospheric drag would ensure that a failed satellite or debris from a collision would demise in a matter of weeks, whereas the same issues

occurring at an altitude of 1,000 km would change the risk landscape for centuries. In addition, as illustrated in Figure 1 below, this approach takes into account the fact that NGSO satellites deorbiting from altitudes above 1,000 km must pass through a region of space with a relatively high concentration of orbital debris on their way to atmospheric demise.

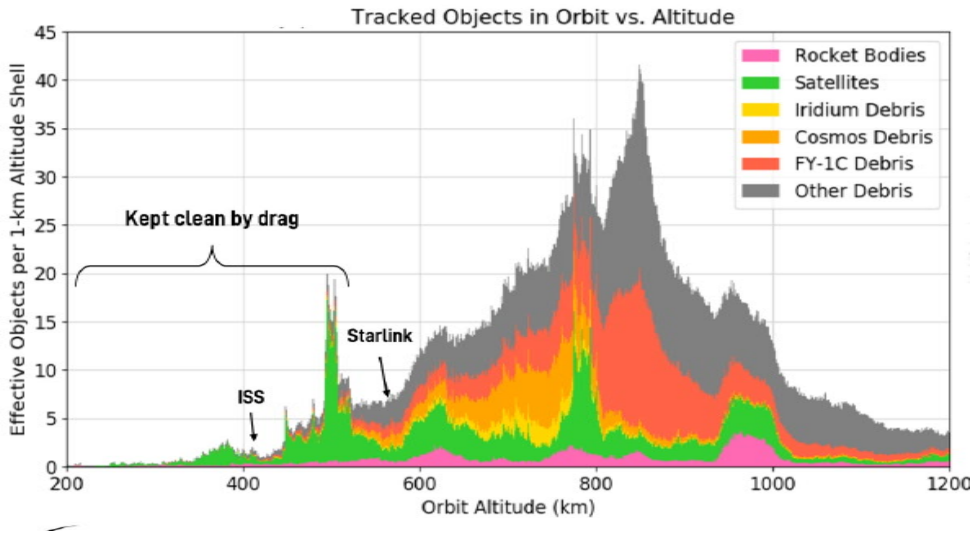

Figure 1. Orbital Debris by LEO Altitude

These altitudes are also characterized by a relatively high concentration of smaller objects (i.e., below 10 cm in diameter) that are not tracked. As Viasat pointed out in a prior submission, "'An impact from a 5-centimeter object—the middle of the range—is the equivalent of being hit by a bus traveling at highway speed'" while "[s]pace debris in the 1 cm to 5 cm (and larger) range 'has the potential to cause catastrophic damage to an active satellite.'"[17] In case of a collision at these higher altitudes, in addition to the danger from a debilitated satellite, the resulting debris clouds could last for thousands of years, increasing the risk of more collisions or effectively precluding the use of certain orbits.

[17] *See Letter from John P. Janka to Marlene H. Dortch*, IB Docket No. 18-313, at 6 (Apr. 10, 2020) (quoting Roger Thompson, "A Space Debris Primer," CROSSLINK, 5-6 (Fall 2015), https://aerospace.org/sites/default/files/2019-04/Crosslink%20Fall%202015%20V16N1%20.pdf.)

These sorts of considerations led SpaceX to seek authority to operate at altitudes below 600 km, where even in the case of satellite propulsion failure or collision, atmospheric drag ensures that the orbital environment will be affected only for a matter of years and not centuries. While other large U.S.-licensed NGSO systems have been licensed to operate at these lower altitudes,[18] foreign-licensed NGSO systems—which often ask to be exempted from the Commission's orbital debris rules—continue to propose operation at higher altitudes where inoperable satellites and related debris would pose an ongoing threat for hundreds of years or more.[19]

To illustrate the calculation of this proposed metric, consider the case of an NGSO system of 1,000 satellites designed to be fully maneuverable throughout their operational lifetime. DAS estimates that an inoperable satellite would passively decay from the proposed operational orbit over an average period of 60 years and has a probability of collision with large debris of 0.01 over that period. For purposes of this illustration, we assume a 1% risk that a satellite would lose maneuverability. Thus, the metric would be calculated as the collision risk times the assumed probability of non-maneuverability times the mean duration of passive decay, or

$$(0.01)*(0.01)*(60 \text{ years})=0.006.$$

This metric assigns a per-satellite value that enables a more accurate comparison of the potential risks presented by each proposed NGSO satellite system.

Even under the current system, one potential complication in making these calculations is that DAS only reports up to 100 years of decay time and will zero out any risk after 2130 – even if a satellite or piece of debris is nowhere near reaching atmospheric demise. This limitation would

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[18] *See, e.g.*, *Kuiper Systems LLC*, 35 FCC Rcd. 8324 (2020) (operating at 590/610/630 km altitudes); Grant Stamp, IBFS File Nos. SAT-LOA-20151123-00078 and SAT-MOD-20200603-00065 (Sep. 18, 2020) (authorizing Spire Global, Inc. to deploy and operate 1,000 satellites at a range of altitudes below 650 km).

[19] *See, e.g.,* Application, IBFS File No. SAT-MPL-20200526-00056 (May 26, 2020) (Viasat request to operate at 1,300 km); Application, IBFS File No. SAT-MPL-20200526-00062 (May 26, 2020) (OneWeb request to operate at 1,200 km).

seriously skew any analysis of satellites operating at altitudes above approximately 800 km, which will certainly take far longer than 100 years to passively demise. SpaceX therefore encourages NASA to assign representative duration-versus-altitude tables for higher altitudes. But until then, the Commission should recognize that DAS calculations are skewed to favor systems at high altitudes. Adopting SpaceX's proposal to better account for the risks accumulating from the increased orbital years at these higher orbits should help provide proper incentives in the meantime.

In making these calculations, the Commission must also consider the manner in which an NGSO operator intends to replace satellites in its system during the license term. If the operator intends to actively de-orbit satellites at end of life to make room for replacements, then the replacement should not change the risk assessment. The total number of satellites in orbit over the life of the license term would remain essentially unchanged in that scenario. On the other hand, if the operator intends to simply move its end-of-life satellites to a "graveyard orbit" from which they will demise over time, then those retired satellites should be counted against the risk assessment as well. For example, if a system licensed for 100 operational satellites expects to replace 10 of those satellites over the license term while placing the retired satellites in a graveyard orbit, those 10 satellites should be assessed for collision risk as they passively decay; their risk should then be added to that of the 100 licensed satellites and that total divided by 100 to reach a mean value for consideration. The number of replacement satellites included in this risk assessment should be based on planned operational lifetime of the system's satellites as stated in the application.

II. THE COMMISSION SHOULD ADOPT OTHER PROPOSALS THAT SIGNIFICANTLY REDUCE RISK FOR OPERATIONS IN SPACE AND LIFE ON EARTH

SpaceX supports other Commission proposals that would impose more stringent space safety requirements on NGSO system operators. In particular, below are three proposals that the Commission should implement to promote the long-term health and safety of NGSO operations by significantly reducing the risk during in-orbit operations and as a result of satellite demise. Specifically, the Commission should require maneuverability for LEO spacecraft operating above the ISS, shorten post-mission orbital lifetime, and require zero calculated risk to human life on the ground.

A. The Commission Should Require Maneuverability for LEO Spacecraft Operating Above the International Space Station

The ISS operates at an altitude of approximately 400 km. The areas around and immediately above the ISS are home to precious cargo, especially human lives given that the station has been continuously occupied since November 2000. Unfortunately, as recently noted by the Administrator of NASA, the threat from orbital debris is getting worse. The ISS has had to maneuver three times in 2020 to avoid debris, and experienced three other high concern conjunctions over a two week period.[20] Anyone wishing to deploy satellites that will transit through the ISS's orbit has a heightened obligation to take special care to operate responsibly. Moreover, while SpaceX is the first private company to successfully deliver astronauts to the ISS,

[20] *See* Jim Bridenstine (@JimBridenstine), TWITTER (Sep. 22, 2020), https://twitter.com/JimBridenstine/status/1308540671725318144.

other operators are also gearing up for crewed missions to altitudes around the ISS – specifically those ranging from 300 km to 600 km – in the near future.

Accordingly, SpaceX supports the Commission's proposal to adopt a maneuverability requirement for spacecraft operating above 400 km that will pass through the ISS's orbit on the way to atmospheric demise.[21] That is the best way to protect the people who work aboard an iconic international science installation, as well as other manned space missions that will operate in this region of space in the future. SpaceX applauds the operators filing recent applications demonstrating that even the smallest satellites can be designed to include propulsion and maneuver capabilities.[22] Moreover, as noted in the *FNPRM*, a maneuverability requirement would have the added benefit of ensuring that the burden of collision avoidance is more evenly distributed among NGSO operators, since all Commission-authorized satellites would have some collision avoidance capability and could take their share of the responsibility for space safety.[23] Thus, the benefits of a maneuverability requirement are both significant and achievable.

B. The Commission Should Shorten Satellites' Allowable Post-Mission Orbital Lifetime

The current demise time of twenty-five years is significantly longer than necessary for most contemporary missions, given current technology. Yet under the orbital debris mitigation rules recently updated by the Commission, "successful disposal" of spacecraft that will be disposed of through atmospheric re-entry is defined as atmospheric re-entry of the spacecraft within 25 years

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21 *See FNPRM* ¶ 164.

22 *See, e.g.*, Application for Modification, IBFS File No. SAT-MOD-20200501-00040, at 4-5 (May 1, 2020) (discussing a "dual-mode system [that] leverages the benefits of cold gas and electric propulsion to maintain the small 1/4U form factor critical to Swarm's deployment model, while providing enough impulse to perform station keeping, spreading, collision avoidance maneuvers, and aid in post-mission disposal"); Petition for Declaratory Ruling, IBFS File No. SAT-PDR-20190328-00020, Attachment A at 2 (Mar. 28, 2019) (discussing Myriota's plan to deploy an upgraded 6U form factor on which "added propulsion capability will be used to conduct orbital station keeping, plane phasing (utilizing the J2 perturbation), collision avoidance, and de-orbit maneuvers").

23 *See FNPRM* ¶ 164.

or less following completion of the mission.[24] Similarly, NASA's recent update to the U.S. Government's Orbital Debris Mitigation Standard Practices ("ODMSP") includes guidance that the post-mission lifetime be "as short as practicable but no more than 25 years."[25] SpaceX supports the Commission's proposal to adopt a requirement that satellites in the LEO region be removed from orbit as soon as practicable, but no more than five years following the end of the mission.[26] As the number of satellites in orbit increases, rules that hasten demise will be crucial in removing inactive objects and promoting a safer orbital environment.

C. The Commission Should Presumptively Require Zero Calculated Risk of Human Casualty

No satellite has ever caused a known case of human casualty. Nonetheless, as the number of satellites in orbit continues to grow, the Commission can and should incentivize satellite operators to build on this perfect record by striving for zero risk of human casualty. As the *FNPRM* notes, "[t]he revised ODMSP states that for those spacecraft disposed of by re-entry into Earth's atmosphere (either by disposal maneuver or using atmospheric drag alone) the risk of human casualty from surviving components with impact kinetic energies greater than 15 joules should be less than 0.001 (1 in 10,000)."[27] The ODMSP also states that "[d]esign-for-demise and other

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[24] *See* 47 C.F.R. § 25.l14(d)(14)(vii)(D)(1).

[25] *U.S. Government Orbital Debris Mitigation Standard Practices*, at 4-1.b (Nov. 2019) ("ODMSP"), https://orbitaldebris.jsc nasa.gov/library/usg_orbital_debris_mitigation_standard_practices_november_2019.pdf.

[26] *FNPRM* ¶ 172.

[27] *Id.* ¶ 173.

measures, including reusability and targeted reentry away from landmasses, to further reduce reentry human casualty risk should be considered."[28]

While requiring no risk to human life on the ground will set satellite broadband at a slight competitive disadvantage compared to terrestrial technologies that have no casualty metric associated with their deployment, it will also ensure the risk posed to human life on the ground from satellites is virtually nonexistent. SpaceX believes that this is a goal the Commission should pursue for each and every satellite that will demise in the Earth's atmosphere. Accordingly, SpaceX supports a requirement that proposed NGSO systems demonstrate zero risk of human casualty from components that survive atmospheric demise of a satellite.

To accommodate the few cases in which achieving this goal may not be practicable, the Commission could establish zero casualty risk as safe harbor and allow applicants to make individualized showings for levels up to a maximum of 0.001 per satellite where justified in particular circumstances.[29] For example, a number of systems are already in development, and equity may require that this metric be relaxed for such systems over the next several years. As this requirement becomes more established over time, the threshold for granting such a waiver should increase as well.

CONCLUSION

SpaceX applauds the Commission's ongoing efforts to update its orbital debris mitigation requirements to promote a safe operating environment in space for all who would make productive use of this valuable shared resource. The Commission has the opportunity to enhance its rules by adopting rules that will require NGSO satellite operators to meet higher but achievable safety

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[28] ODSMP at 4-1.a.

[29] *FNPRM* ¶ 174. In addition, in cases where other agencies authorize space vehicles (such as second stages of launch vehicles), the Commission should defer to the expertise of the authorizing agency.

goals, such as by more fully accounting for the effects of leaving satellites in orbit for decades, centuries, or millennia. At the same time, the Commission should refrain from adopting new rules with unclear, if any, benefits but certain harm such as by discouraging satellite deployment and investment while establishing disparate safety requirements for satellites based solely on the number authorized for a particular operator. Finally, for any rules to be effective, the Commission must apply them fairly and evenly, not just to U.S.-licensed operators.

Respectfully submitted,

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